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MISSION

To collect and archive information about the geologic character, processes, hazards, and mineral and energy resources of Arizona and to inform, advise, and assist the public in order to foster understanding and prudent development of the State's land, water, mineral, and energy resources.

GOALS

- Increase understanding of the geology of areas with potential population growth and economic development
- Improve effectiveness of administering Arizona's oil and gas statutes
- Expand the customer base of the Arizona Geological Survey
- Improve access to digital geologic information to all users

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Catastrophic Natural Disasters in Arizona?

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January 01, 2001 was the first day of the third millennium. During the last months of the second millennium, catastrophic volcanic eruptions, landslides, and earthquakes caused many deaths and extensive property damage throughout the world. The death toll from a single earthquake in India in January may reach 35,000, although an accurate count may never be possible. Are similar disasters likely to happen in Arizona? A brief review of past geologic activity and trends provides clues that enable one to speculate about geologic activity that could take place in Arizona during the third millennium.

Volcanoes and earthquakes. Volcanic eruptions and earthquakes are among the worst natural disasters in terms of deaths and property damage. Volcanic eruptions were common in Arizona numerous times during the past several hundred million years. Even though none of these volcanoes are currently active, they may be dormant rather than extinct. The only eruptions known to have happened in Arizona during the second millennium began at Sunset Crater near Flagstaff about 1064 A.D. and continued sporadically for about 150 years (Figure 1). Explosive eruptions have also occurred in Arizona in the geologic past, although the most recent was at San Francisco Mountain, near Flagstaff, 200,000-400,000 years ago. There is no evidence that magma is moving upward toward the land surface beneath Arizona today to cause another eruption.

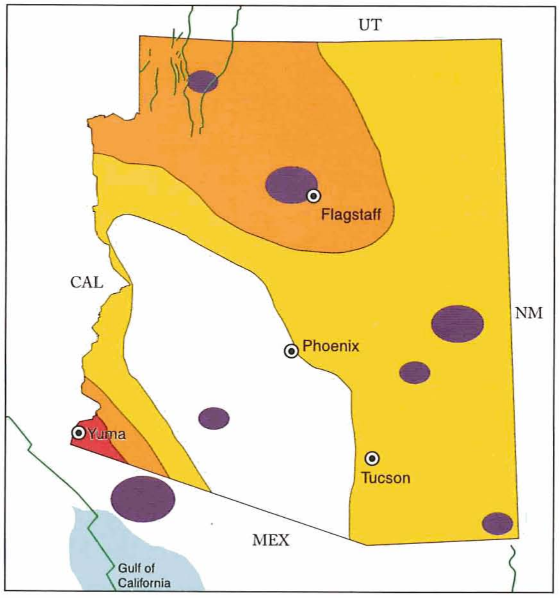

Figure 1. *Youngest volcanic eruptions, major faults, and estimated earthquake hazards in Arizona are shown. Volcanic centers one million years old or less are shown in purple. Major faults that have potential for movement are shown in green. Areas with high, moderate, and moderate to low earthquake hazards are shown in red, orange, and yellow, respectively.*

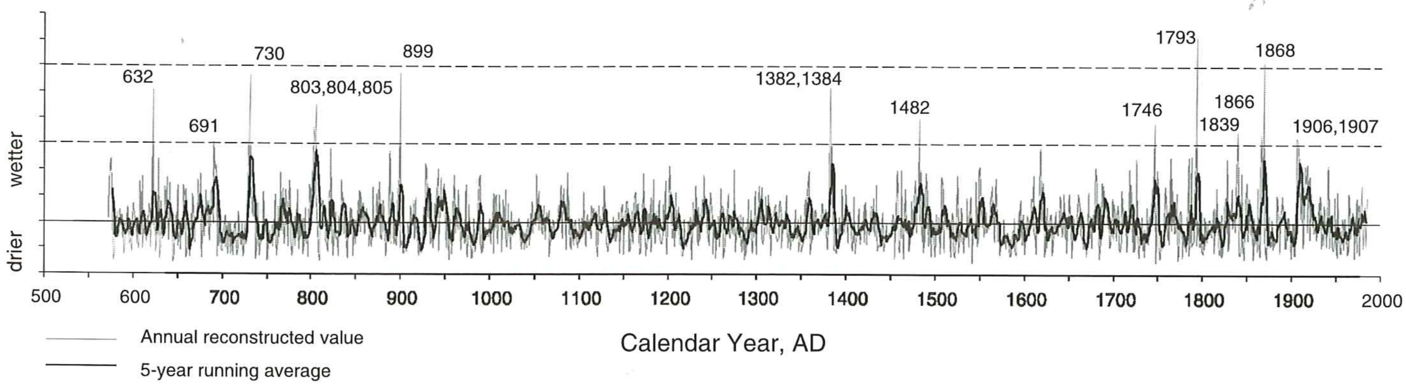

Figure 2. *A reconstruction of annual stream flow for the Verde River based on tree-ring data shows the cyclical nature of wet and dry climatic periods over the past thousand years. This figure is from House and others (2001), and is based on unpublished data from Donald Graybill and Gary Funkhouser.*

At least 40 faults have been identified that caused ground rupture and generated earthquakes in Arizona during the past million years (Pearthree, P.A., and Bausch, D.B., 2000). Since 1852, thirteen earthquakes with magnitudes greater than 5.0 occurred in or near enough to Arizona to cause damage. The Hurricane and Toroweap Faults in northwestern Arizona probably generated magnitude 7.0 earthquakes within the past 10,000 years. Movement along faults in southern California's Imperial Valley in historic time caused earthquakes with similar magnitudes. Some of them caused property damage in Yuma. These faults are shown in Figure 1.

A strong earthquake (magnitude 7.25) shook southern Arizona in 1887. This major event, felt over a large area, was generated by movement along a 50-mile-long fault in northernmost Sonora, Mexico, southeast of Douglas, Arizona. The northern end of the fault was only 5 miles south of the U.S.-Mexico border. Ground shaking caused deaths and extensive property damage in Sonora, but only property damage in southern Arizona. Geologists who studied displacement along the fault concluded that tens to hundreds of thousands of years passed between major earthquakes.

Geologists interpret the earthquake hazard on the basis of frequency, magnitude, and location of historic earthquakes and the character of displacement along prehistoric faults. On this basis they have concluded that the Yuma area has the greatest hazard; the Flagstaff-Williams-Grand Canyon area is second (Figure 1).

Floods and climate. Floods have caused substantial property damage in Arizona. Most of us remember the major floods in 1983 and 1993, and the near miss from rains associated with Hurricane Nora in 1997. Prehistoric floods are difficult to characterize because the deposits they left were soft and eroded easily. Evidence of prehistoric floods as large or larger than historical floods has been documented along most of the major rivers in the state.

Tree rings from the Verde River basin indicate that cyclical wet and dry periods occurred before and during the second millennium (Figure 2). The period between about 900 and 1350 A.D., when the Hohokam culture flourished in central and southern Arizona, was characterized by relatively little variation between wet and dry years. On the other hand, the past few hundred years have included many very wet years and some extended dry periods.

Weathering, erosion, and climate change. Weathering processes cause rock to decompose, disintegrate, and subsequently, be eroded. Although these processes take place constantly, they typically modify the landscape so slowly that change may not be noticeable during a human lifetime. Landforms in Arizona today probably look much like they did 1,000 years ago.

Rates of weathering and erosion are determined partly by temperature and amount of rainfall, both of which fluctuate continuously. The average annual temperature is usually either rising or falling and is never static for a long period of time. Observed climatic changes occurred over widespread areas, probably on a global scale.

Scientists throughout the world have done extensive research, especially during the last 20 years, on past climatic conditions. During the last 60 million years, except for a peak about 50 million years ago, temperatures in central Europe (and probably worldwide) decreased about 15^{0}C before the Ice Age (Pleistocene Epoch) began a couple million years ago (Figure 3). During the Pleistocene, temperature and rainfall fluctuated quickly (geologically speaking) and often. During cool, moist times glaciers formed and spread southward across the Midwest and New England and outward from mountains in the western United States. Sea level dropped. During the warm, dry times the ice melted, glaciers receded, and sea level rose. The only glacial deposits described in Arizona are on San Francisco Mountain near Flagstaff.

Climatic changes measured during the last hundred years are not unique or even unusual when compared with the frequency, rate, and magnitude of changes that took place during the past 10,000 years (Bluemle, 1999). Recent fluctuations in temperature that are currently receiving much publicity are well within the limits observed in nature *prior* to human influence.

Population growth. Population growth and related development, although not geological phenomena, have impacted Arizona's landscape significantly. Early in the second millennium when the Hohokam began building irrigation canals, pit houses, and living compounds, what is now Arizona was sparsely populated. Population increase began after the Civil War, when gold, silver, copper, and other metallic minerals were discovered. At Statehood in 1912 the population exceeded 200,000. Population growth dramatically accelerated in the late 1940s and early 1950s, immediately after World War II (Figure 4). Ground-water usage increased correspondingly as the population grew. Arizona now has more than 5,000,000 residents and the population is increasing steadily. As the population increases, the demand for land, water, and mineral and energy resources will also increase.

Conclusions. Geologic evidence suggests that catastrophic volcanic eruptions are not likely to be a threat in Arizona during the third millennium. Although earthquake frequency in Arizona is low, a well-defined earthquake hazard exists. Damaging earthquakes in the 6.5-7.0 magnitude range can be expected, especially in the Yuma and Flagstaff areas.

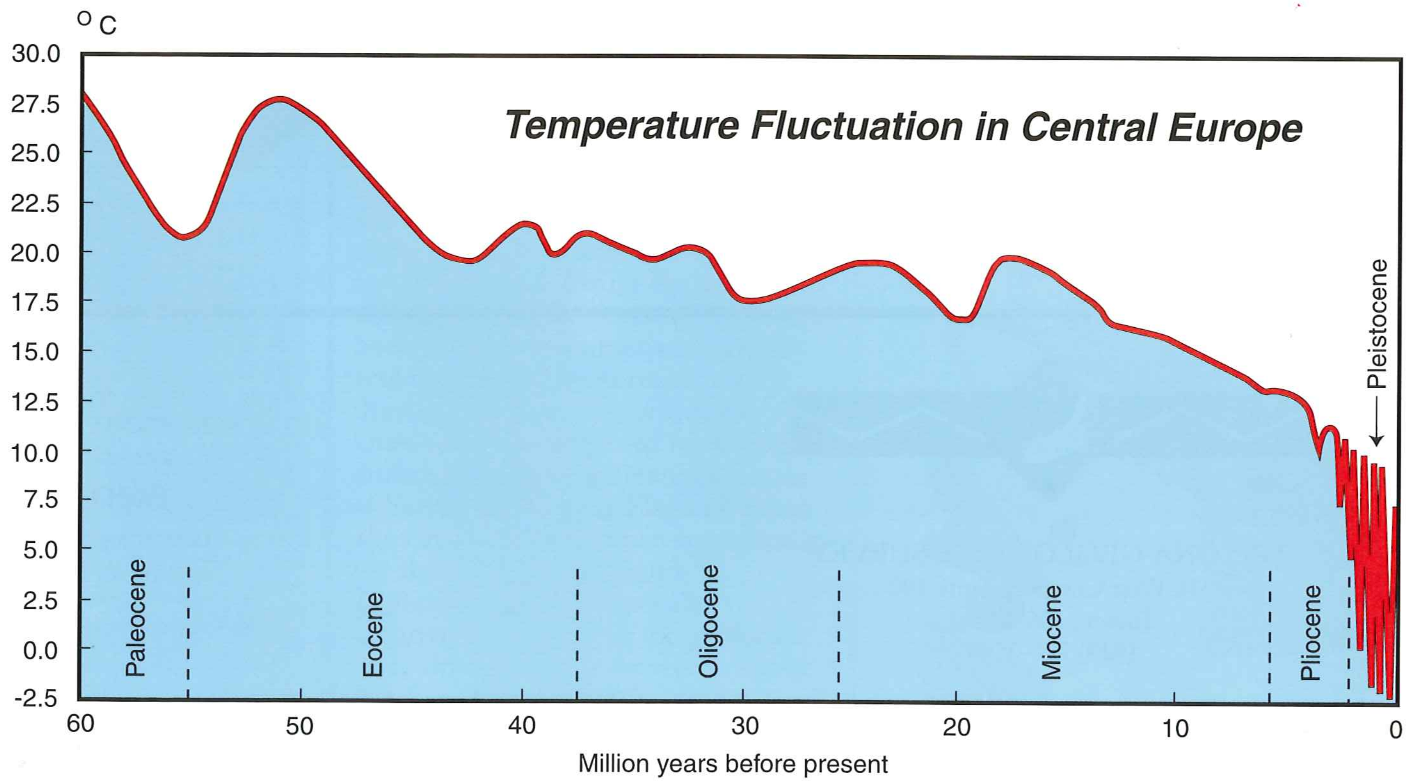

Figure 3. *Temperature change in central Europe during the past 60 million years. The modern condition is approximately +4 to +5 degrees Celsius. Graph is modified and adapted from Anderson, B.G. and Borns, H.W., 1997, The ice age world: Oslo, Scandinavian University Press.*

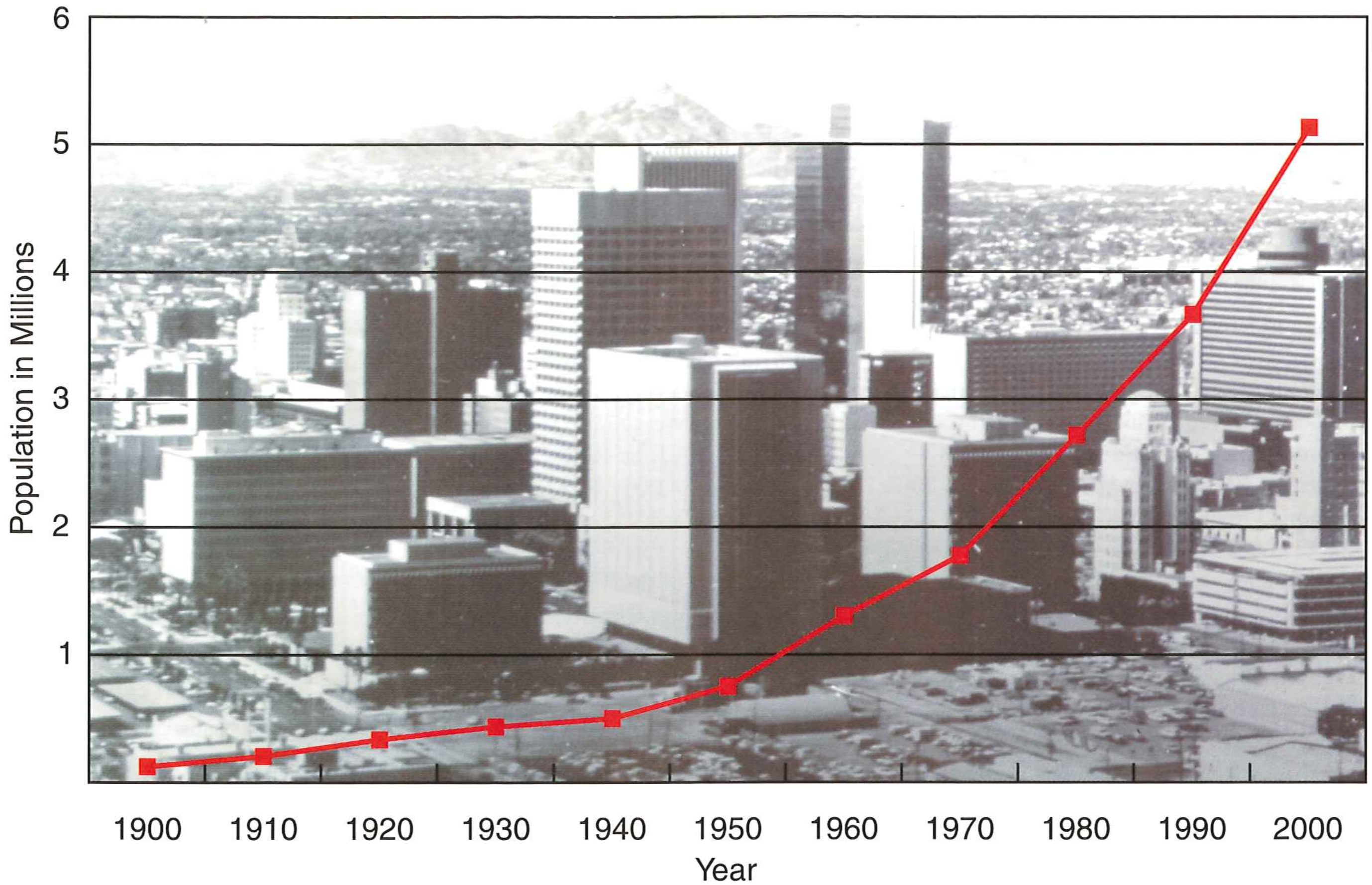

Figure 4. *The population in Arizona increased dramatically after World War II.*

The annual temperature and amount of precipitation will continue to fluctuate, as they have for thousands of millennia. Because of the cyclical nature of rainfall, flooding will happen periodically.

Increased pumping of ground water has already caused the land to subside and earth fissures to form in numerous parts of southern Arizona. If ground-water pumping is not controlled sufficiently, land subsidence will continue, existing earth fissures will extend, and new ones will form. Some of the new fissures will develop in valleys where problems have not existed previously.

Arizona faces some potentially serious hazards and limitations to land and resource management that are caused by geologic processes. These hazards and limitations are not nearly as severe, however, as they are in other parts of the nation or the world.

Selected References

Bluemle, J.P., 1999, *Global warming: A geological perspective*: Arizona Geological Survey, Arizona Geology, v. 29, no. 4, p. 1-4.

Pearthree, P.A., and Bausch, D.B., 2000, *Earthquake hazards in Arizona: Arizona* Geological Survey Map 34, text and map, scale 1:1,000,000.

House, P.K., Pearthree, P.A., and Klawon, J.E., 2001, *Paleoflood history of the lower Verde River, Yavapai County, central Arizona*: Arizona Geological Survey Open-File Report 01-04, 34 p.